Interaction between length and curvature in haptic shape perception

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2014

SUMMARY

In this thesis, the influence of local features, mainly length and curvature, on the perception of global shape was investigated. In the introduction, it was explained that this objective consists of two parts: one part considers the local features in the shape, the second part considers specific exploration strategies. To explore these two aspects, four subquestions were formulated, which when put together shed more light on the main problem. The first question that was answered was whether local features can influence perception of a global feature. Once it was known that perception of global shape could be influenced by local features, the next question was how curvature and length are combined in bimanual exploration. This combined investigating different features in the shape with different specific methods of exploration. The third question was how different features of a shape are combined in unimanual exploration. This focussed on the features in an object and their interaction. The final question was what the mechanism behind the difference in precision between unimanual and bimanual exploration was in the perception of only length.

In Chapter 2, we investigated the effect of length, curvature, edges and change in curvature on the ability to determine the orientation of shapes. Depending on the condition, subjects were presented with either a cylinder with an elliptical cross-section or a block with a rectangular cross-section. The difference from circular or square, respectively, was varied such that a discrimination threshold could be determined for each condition. We compared conditions with curvature and without curvature, with change in curvature and without and finally with edges and without edges. The results showed that curvature and change in curvature lower the threshold for detecting the orientation of a shape, but edges increase the threshold. We concluded that if edges are not an informative cue they hinder perception of global orientation of shape, whereas the presence of change in curvature and curvature increase the ability to detect orientation.

In Chapter 3, the focus was on the difference between unimanual and bimanual perception of shapes with both length and curvature features. In the main experiment, subjects felt curved stimuli and had to indicate whether the position of the stimuli was too far away from or too close by their midsagittal plane to form a cylinder with a circular cross-section centered on their midsagittal plane. This required subjects to use the perception of both the position and the curvature of the stimulus. We found that subjects were more precise in the bimanual condition than in the unimanual condition. In the sec-

ond and third experiment of this chapter we found that discrimination of position does not differ in the unimanual and bimanual conditions and that subjects are more precise in determining the location of their midsagittal plane than the position of a stimulus. From this we concluded that it is the curvature that is responsible for the better performance in the bimanual condition and that curvature is integrated between the two hands.

In Chapter 4, we looked at how different features in a shape are combined. To investigate this, we focussed on curvature and length. By comparing how well subjects can identify shapes based on only length, only curvature and on length and curvature combined, we concluded that length and curvature are integrated when both are present in a shape and this makes identification of the shape more precise. We also investigated whether the way in which the cues are combined affects the precision. We found that when length and curvature are combined as in a circle, identifying a shape is more precise than when they are combined in an anti-correlated way, i.e., when the length is small, the curvature is small as well. We speculated that this is due to length and curvature in daily life mostly being combined in a circular way.

In Chapter 5, the manner of exploring one aspect of shapes, namely length, was investigated. We postulated three hypotheses that could explain why free bimanual exploration of length would be less precise than unimanual exploration. Firstly, it could be due to the two hemispheres of the brain involved in bimanual exploration, which would make discrimination more difficult and therefore less precise. Secondly, it could be due to the difference in the kinesthetics involved. In two hands, differences in the position of the tips of the index finger have to be perceived from, for example, the elbow joint angles. In contrast, in unimanual exploration the angles that have to be perceived are much closer to the finger tips. Smaller changes can be perceived when the distance between the joint and the finger tips is smaller, which would make unimanual discrimination of length more precise. Finally, the difference in the reference frame in which the discrimination is taking place could affect the perception. In free bimanual exploration, the only reference frame is the egocentric one with the origin in the body. In the unimanual reference frame there is the egocentric reference frame with the origin in the hand. The difference in length could be easier to represent or calculate in one of the reference frames, making discrimination in that reference frame more precise. From comparing the four conditions in this experiment, we concluded that discrimination is better in a hand centered reference frame.

In the final chapter, the results were discussed in the context of shape perception. The general conclusion was that when feeling a shape, more features that give cues about the global feature of interest, give a more precise perception of the global shape and when curvature is present, feeling with two hands is more precise than feeling with only one.